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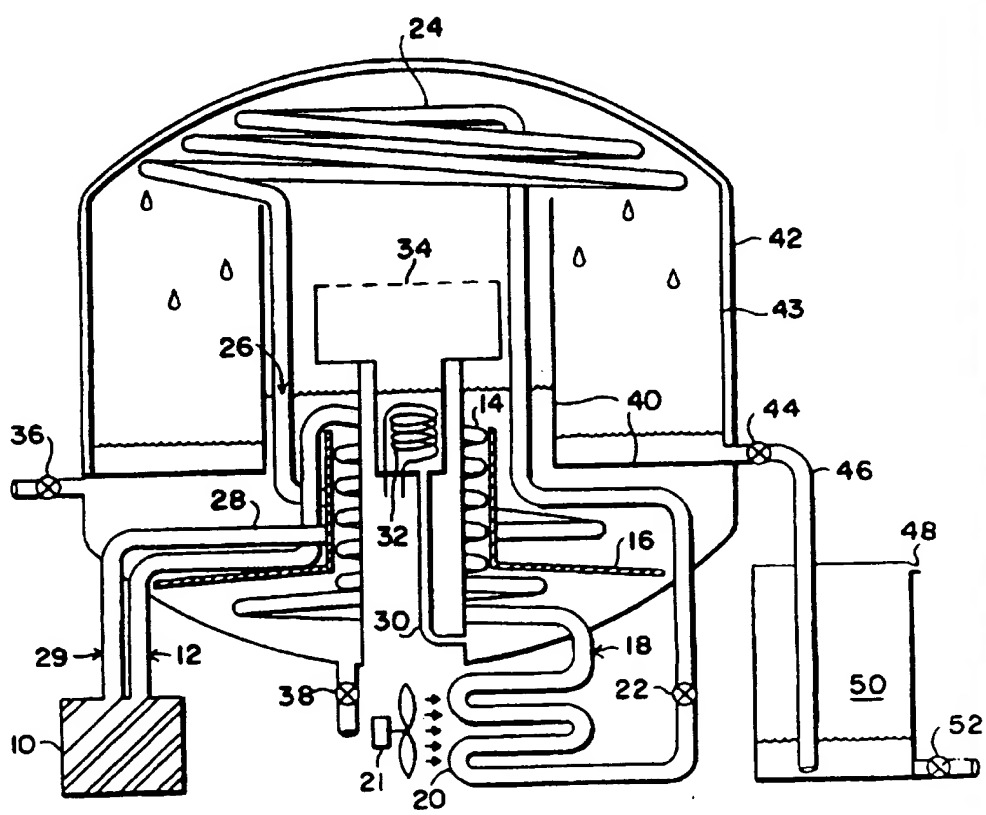
(54) Title: COMPACT VACUUM DISTILLATION DEVICE

(57) Abstract

Disclosed herein is a compact vacuum distillation device for the distillation of liquids. The device comprises an evaporator (14) in which liquid is evaporated and a condenser (24) where the liquid is condensed, both evaporator (14) and condenser (24) units are contained within the same distiller vessel (42). A refrigeration cycle (14, 28, 24, 10) is used to supply heat to boil the liquid being distilled and to condense the vapor. The distiller vessel (42) also includes a novel heater vacuum generator (30, 32, 34) which creates a vacuum inside the vessel. This vacuum allows boiling of the liquids at a reduced temperature thus allowing the use of a refrigeration system as the heating and cooling source that reduces energy consumption. The device will produce distilled liquid at a cost less than 25 - 50 % of simple distillation. Due to the compact size and the use of the same components as a conventional refrigerator, this device can be integrated into the refrigerator system and produce distilled water.



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COMPACT VACUUM DISTILLATION DEVICE

Background - Cross Reference to Related Inventions

None.

Background - Field of the Invention

This invention relates to vacuum distillation devices and specifically, to such devices that are compact and incorporate a refrigerant cycle and utilize components which result in low energy consumption.

Background - Prior Art

The process of distillation has long been in use for the production of clean water and other liquids. The water enters a boiler where it is evaporated. The steam then passes through a cooling chamber where it condenses to form droplets of pure water that pass to the distillate outlet. Distillation is the only water purification process that removes, with certainty any solids contained in the feedwater.

There are a number of recognized disadvantages in the simple distillation system where water boils at 212 $^{\circ}F$. The first is the energy consumption required to boil the water and to remove the excess heat from the condensate. Another practical disadvantage is the tendency to scaling that occurs at higher temperatures. In the case of large-scale distillation systems, a number of solutions have already been developed. For instance multistage distillation, where some of the latent heat of evaporation is recovered from one distillation stage to provide heat for the next stage. In each stage the pressure and therefore the boiling temperature drops.

Another such solution is the use of a vapor compression distillation device that reduces even further the energy requirements of large scale distillation systems. In vapor compression distillation, the water is evaporated by boiling

and the resulting vapor is then compressed, which increases the vapor pressure and therefore temperature.

This vapor is then used to heat up the water in the boiler and in this manner, the latent heat is recovered. Once the vapor compression distillation cycle is started, little further heat is required and the only energy requirement is for the vapor compressor itself.

In the case of small scale distillation systems, in the order of 250 gallons per day or less, the capital costs of multistage distillation and vapor compression distillation make these alternatives unacceptable. Thus all small scale distillation systems use simple distillation at atmospheric pressure and temperature.

The present invention incorporates a number of improvements over conventional simple distillation, such as heat recovery using a refrigeration cycle. Also the present invention creates a vacuum without use of an expensive mechanical pump and combines the normally separate boiler and condenser into one integrated unit.

The result of these innovations is a system that produces high purity distilled water in a batch process, for considerably less energy consumption than the simple distillation method. Also, another advantage of low temperature distillation is the elimination of scaling from the impurities that normally exist in water.

Objects and Advantages of the Invention

Accordingly, besides the objects and advantages of the vacuum distillation system described in my patent above, several objects and advantages of the present invention are:

(a) The main object and advantage of this invention is a novel vacuum distillation process for the production of high purity water, using less energy than conventional simple distillation systems .

(b) Another object and advantage of the present invention is an innovative method of creating a vacuum in the system, which eliminates the need for a mechanical vacuum pump.

(c) Another object and advantage of the present invention is the use of a heater vacuum generating device to allow the distillation of water at low temperature.

(d) Another object and advantage of the present invention is the reduction of scaling on the boiler and condenser units, due to the lower boiling point used thus eliminating the need for descaling and the use of descalant chemicals.

(e) Another object and advantage of the present invention is the use of lower-cost materials due to the lower operating temperatures of the device.

(f) Another object and advantage of the present invention is the lower boiling temperature makes the device safer to handle and operate.

(g)Another object and advantage of the present invention is the combining of the normally separate boiling and condensing functions in a single vessel.

(h) Another object and advantage of the present invention is an innovative method of using an enhanced circulation heat transfer device, which allows a significant reduction in the overall size of the boiler.

(i) Another object and advantage of the present invention is the ease of integration of the invention into the design of a standard refrigeration system, where the refrigerator's condenser and evaporator components can be made integral with the same components in the device.

Brief Description of the Drawings

Figure 1a is a sketch of a typical stand alone batch process distillation unit

Figure 1b is a partial cross section of a stand alone batch process distillation unit, showing the various components of the design.

Figure 2a is a schematic of a typical standard household refrigerator showing the location of the batch process water distillation unit.

Figure 2b is a partial cross section of a batch process distillation unit with its own refrigerant evaporator and integrated into a standard household refrigerator.

Figure 2c is a partial cross section of a batch process distillation unit without its own refrigerant evaporator and integrated into a standard household refrigerator.

List of Reference Numerals

4	Outer Cover
6	Support Base
8	Refrigerator Case
10	Refrigerant Compressor
11	Electrical Power Chord
12	Refrigerant discharge line, start of water evaporator
14	Refrigerant condenser, water evaporator
16	Refrigerator condenser shroud
18	End of water evaporator
20	Radiator
21	Forced draft fan
22	Refrigerant pressure reducing device I
24	Refrigerant evaporator I and steam condenser
26	End of steam condenser, start of the heat exchanger
28	Heat exchanger
29	Suction line of refrigerant compressor
30	Liquid supply connector tube of vapor generator device
32	Heater element of vacuum generator device
34	Vapor separator of vacuum generator device
36	Water inlet valve
38	Drainage valve
40	Distillate collector
42	Distiller vessel
43	Vessel Insulator liner
44	Distillate/air outlet valve

46	Connector tube between distiller vessel and distillate reservoir
48	Air Discharge Vent
50	Distillate reservoir
52	Distillate discharge valve
54	3-way solenoid valve I
56	3-way solenoid valve II
58	Refrigerant pressure reducing device II
60	Refrigerant evaporator II
62	3-way solenoid valve III

Static Description of the Figures

Figure 1a shows a typical embodiment of the invention for distillation of water. The embodiment has a compressor (10), a distiller vessel (42) as shown in Figure 1b, which combines a water evaporator (14), a vacuum generator device (30) to (34), a steam condenser (24) and a distillate collector (40), in one integrated unit and a radiator (20) and a distillate reservoir (50). The embodiment also has a water inlet valve (36), an electrical power chord (11) and a distillate discharge valve (52) and a drainage valve (38), mounted on a support base (6) and the whole embodiment is encased in an outer cover (4).

Figure 1b shows a detailed view of a stand alone distillation unit which has an outer metal or plastic distiller vessel (42), with a insulator liner (43); the distiller vessel contains a vacuum generating device, made up of a connector tube (30), a heater element (32), and a vapor separator (34).

The distiller vessel (42) also contains a refrigerant condenser coil (14), a refrigerant condenser coil shroud (16), a heat exchanger (28) and a refrigerant evaporator (24) and a water distillate collector (40).

On the outside of the distiller vessel (42) is attached a water inlet valve (36), a distillate/air outlet valve (44) and a drainage valve (38). Connected to the distiller vessel (42) is a refrigerant compressor (10), a radiator(20) that includes a refrigerant pressure reducing device I (22). The radiator (20) may include a forced draft fan (21).

The distillate reservoir (50), which has a small air discharge vent (48) at the top and a distillate discharge valve (52), is connected to the distiller vessel (42), by a connector tube (46).

Figure 2a shows a schematic of a typical embodiment of the present invention, integrated into a standard household refrigerator. The schematic shows a distiller vessel (42), which combines a water evaporator (14), a vacuum generating device (30) to (34), a steam condenser (24), a distillate collector (40), a heat exchanger (28) and a shroud (16), in one integrated unit and a compressor (10), a radiator (20), a distillate reservoir (50) and a refrigerant evaporator II (60).

Figure 2b shows a detailed view of a partial cross section of a distillation unit with its own refrigerant evaporator and integrated into a standard household refrigerator. Details of the distillation unit is the same as described in Figure 1b above, except for the addition of three 3-way valves (54), (56) and (62) and a refrigerant pressure reducing device II (58), connected to the refrigerant evaporator II (60).

Figure 2c is a partial cross section of a distillation unit as described in Figure 1b above except without its own refrigerant evaporator I (24), refrigerant pressure reducing device I (22), two 3-way valves (56) and (62), and a heat exchanger (28), integrated into a standard household refrigerator the same as described in Figure 2b above.

Explanation of how the Invention Works or Operates

In order to explain the operation of the system we will describe the stand-alone version and the integrated versions in the following sections.

1. Stand-Alone Distillation System

The basic principle in the proposed batch process distillation stand-alone system is to boil water in the bottom of the vacuum container to generate steam which then passes to a condenser at the top of the vacuum container. The steam is then condensed to distilled water. The proposed distillation system is shown in detail, in figure 1b. The process of the invention can be divided into the following phases: water filling, vacuum generating, distillate producing, and distillate discharging.

1.1 Water Filling :

Since the invention involves a batch process the first step involves the filling of the distiller vessel (42) with water. To accomplish this, first open distillate/air outlet valve (44) and water inlet valve (36) and close drainage valve (38). Ensure that compressor (10) and heater element (32) are turned off. Fill up distiller vessel (42) with treated water through valve (36) until

liquid level is above the vacuum generator heater element (32), then, close water inlet valve (36). The system has now been charged with water.

1.2 Vacuum Generating :

The following method of creating a vacuum replaces the need for an expensive vacuum pump and is based on a simple heating device which operates as follows: Turn on heater element (32) to generate steam, while the water is continuously supplied to the heater cavity, from connector tube (30). The steam generated by the heater element (32) also heats the refrigerant vapor inside the refrigerant evaporator (24) to a superheated state. In order to cool the superheated refrigerant, the heat exchanger (28) will reduce the superheated refrigerant temperature sufficiently, to allow the vacuum cycle to proceed.

The vapor generated by heater element (32) is pushed out along with the air initially trapped in distiller vessel (42), through distillate/air outlet valve (44), connector tube (46), and distillate reservoir (50) and is finally released from the top air discharge vent (48) of distillate reservoir (50). Some vapor will be condensed in distillate reservoir (50) when some cold distillate exists.

The inside of distiller vessel (42) is lined with a insulator liner (43) to reduce the condensation of steam on its surface which would stop the steam from displacing air from the vessel. The steam generated by heater element (32) will dilute the air in distiller vessel (42) until after a few minutes, the container is eventually filled almost entirely with steam. Then distillate/air outlet valve (44) is closed and heater element (32) is turned off.

From this point on, the pressure in the distiller vessel (42) will correspond to the steam temperature. When the refrigerant compressor (10) is turned on, steam pressure in the distiller vessel (42) will drop down with steam temperature, thus achieving the vacuum condition during operation of the device. This device will produce vacuum conditions in the range of (27-29)"Hg. This occurs even though the incoming water has not been degassed.

1.3 Distillate Producing

The process of distillate production in a stand-alone device is presented in two parts as follows

1.3.1 Water evaporating and refrigerant condensing and

1.3.2 Steam condensing and refrigerant evaporating.

These are both described in detail in the following subsections.

1.3.1 Water evaporating and refrigerant condensing

The compressor (10) is now turned on and the superheated refrigerant vapor is discharged from the compressor (10). The refrigerant superheated vapor is routed to the top portion of the refrigerant condenser (14), which is a tube coil extending from the point (12) to point (18). The refrigerant condenser coil (14) is divided into two portions. The top portion of the coil (14) is contained inside the cylindrical portion of shroud (16) and the bottom portion of the coil (14) is covered by the disk-shaped portion of shroud (16). The batch of water is heated by the refrigerant under vacuum conditions.

The water is preheated at the bottom portion of the refrigerant condenser (14) and continues to heat up to the top portion of the condenser (14). Water that is 1-2 inches below the water level, reaches a superheated condition and creates a steam/water mixture. The steam/water mixture bursts out from inside of the top portion of the shroud (16) and hits the vapor separator (34).

The steam rises through the vapor separator (34) to the refrigerant evaporator I (24), while the water falls down to the outside of the shroud (16). Due to the density difference between steam and liquid, the water outside the top of the cylindrical portion of shroud (16) is forced downwards and then feeds under the bottom plate portion of the shroud (16) and then rises up the inside of the cylindrical part of the shroud (16). This enhanced circulation heat transfer device raises the convection heat transfer between the water and the refrigerant.

Meanwhile, the refrigerant is continuously condensed to a low vapor ratio state by the water. The low vapor ratio saturated refrigerant is then routed to the radiator (20) and continuously condenses to a liquid state.

1.3.2 Steam condensing/refrigerant evaporating

The refrigerant now flows through the refrigerant pressure reducing device I (22) (e.g. expansion valve or capillary tube), into the refrigerant evaporator I (24). The liquid refrigerant temperature drops markedly during the expansion process and the refrigerant becomes a low vapor ratio saturated mixture.

The refrigerant evaporating temperature is selected above $32^{\circ}F$ for water to prevent freezing. The refrigerant inside the refrigerant evaporator I (24), absorbs energy from the steam and the refrigerant evaporator I (24) acts as an evaporating tube to evaporate the refrigerant.

Meanwhile, the steam releases energy and is condensed on the outside of the refrigerant evaporator I (24) which acts as a condenser for the steam in the distiller vessel (42). The condensate falls down to the distillate collector (40). The refrigerant routes into the heat exchanger (28) which extends from point (26) to the inlet of the compressor (10). All refrigerant leaving the heat exchanger should be in single-phase vapor form.

The refrigerant leaving the heat exchanger (28), passes through the suction line (29) to the compressor (10). Here the compression process occurs. The high-pressure vapor then passes through the discharge line to the refrigerant condenser (14), thereby completing the vapor compression refrigeration cycle.

The above refrigeration cycle can also be replaced by an absorption refrigeration cycle. The absorption refrigeration cycle is different from the vapor compression refrigeration cycle as it uses thermal energy instead of mechanical energy to make a change in the conditions necessary to complete a refrigeration cycle.

The use of a refrigeration cycle creates a performance increase by the ratio of the amount of energy released from the refrigerant evaporator I (24) divided by the energy input to the refrigerant compressor (10), thus creating a significant energy saving when compared to a simple distillation system.

The distilled water production is continuous from the above described water distillation loop until the distillate collector (40) is filled.

1.4 Distillate Discharging

The next part of the batch distillation process is discharge of the distillate from the collector into an external reservoir. First open drainage valve (38) which allows air to enter the system and break the vacuum. The distillate outlet valve (44) is now opened and the distillate is discharged by gravity to the distillate reservoir (50). The next cycle will restart at this point.

2. Distillation System Integrated into a Standard Household Refrigerator.

There are two basic preferred embodiments, for integration of the invention into a household refrigerator as described in sections 2.1 and 2.2 below.

2.1 Water Distillation Device with Refrigerant Evaporator

This system is composed of two loops, one is the water distillation loop and the other is the refrigeration loop. In the case of the water distillation loop it is the same as described in section 1.3 above. In the second case the refrigeration loop is controlled by means of three 3-way valves (54), (56) and (62). Thus the refrigerant leaving the compressor (10) to the radiator (20) and through the refrigerant pressure reducing device II (58) enters the refrigerator evaporator II (60) to complete the refrigeration cycle.

2.2 Water Distillation Device without a Refrigerant Evaporator.

This embodiment is the same as that described in detail in section 2.1 above except the refrigerant evaporator I (24) is deleted and the refrigerant is routed into the refrigerator evaporator II (60) and the top of the distiller vessel (42) acts as the steam condenser when it is cooled by cold air supplied from the refrigerator evaporator II (60).

Summary, Ramifications and Scope

Accordingly, the reader will see that the compact vacuum distillation device of this invention can be used to produce distilled water with significantly reduced energy consumption when compared with simple distillation systems. The compact vacuum distillation system has the additional advantages in that:

- it permits the reduction of energy consumption to less than (25-50)% of simple distillation systems

- the size of the vacuum distillation system is reduced due to the combining of the water evaporator and steam condenser into one vessel and the generation of enhanced convection by use of a shroud in the water evaporator.

- it utilizes a device for creation of a vacuum without the use of a vacuum pump, thus allowing use of a refrigeration cycle as a heating source for producing steam.

- the use of the heater vacuum generating device reduces the overall size of the unit.

- it reduces the formation of scaling due to the lower boiling temperature thus eliminating the need for descaling or the use of descalant chemicals.

- the design is easily integrated into a conventional refrigerator where therefrigerator's condensing and evaporating components can be made integral with same components in the device.

- it allows the use of lower-cost materials due to the lower temperatures used.

- it makes the device inherently more safe too use and operate due to the lower boiling temperature created by the vacuum.

While the above description contains many specificities, these should not be construed as limitations on the scope of the invention, but rather as an exemplification of one preferred embodiment thereof.

Many other variations are possible. For example, the vessel can have many other volumetric shapes such as oval, circular, square, etc. and the liquid to be distilled can be other than water such as ethylene glycol, sea water, etc.

Accordingly the scope of the invention should be determined not by the embodiments illustrated but by the appended claims and their legal equivalents.

Claims

We claim,

1. A method of vacuum distillation that comprises of generating a vacuum throughout the system and incorporating a refrigeration cycle where the heat from the hot side of the refrigeration cycle is used to evaporate the liquid to be distilled in vapor form in the vacuum system and the cold side of the refrigeration cycle is used to condense said vapor back into liquid form.

2. A method of generating vacuum by heat where heat is used to vaporize a small quantity of liquid, such that the vapor drives out the air in the distillation vessel and the vessel pressure will diminish once some of the vapor condenses back into liquid.

3. A method for distilling a liquid comprised of introducing the liquid to be distilled, pushing air out of a distiller vessel, by a heater vacuum generating method, as in claim 2, causing said liquid to evaporate and condense by means of a refrigeration cycle.

4. As in claim 3, condensing said liquid vapor by using the cold side of said refrigeration cycle.

5. As in claim 1, where the refrigeration cycle is composed of a vapor compression refrigeration cycle.

6. As in claim 1, where the refrigeration cycle is an absorption refrigeration cycle.

The Claims (Continued)

7. As in claims 1 and 2 where a heat exchanger is inserted between the refrigerant evaporator and the compressor to cool the refrigerant during the heater vacuum generating phase.

8. As in claim 1, wherein a heat source is used to enhance circulation of the liquid to be distilled, so as to enhance the heat transfer between the heater and the liquid without the need of a mechanical pump, resulting in a reduction in size and increase in heat transfer efficiency of the overall system.

9. As in claim 8, wherein a shroud is used to separate the hot and cold part of the liquid being distilled so that the cold part flows underneath the shroud and the hot part flows to the top of the shroud.

10. As in claim 1, where said liquid is water containing other substances and producing distilled water.

11. As in claim 3, where said liquid is water containing other substances and producing distilled water.

12. As in claim 1, where the method of producing distilled water is combined with a refrigerator so that the same compressor can function in both distillation and refrigeration loops to keep the refrigerator cooled and to generate distilled water.

13. As in claim 1, the distillation method utilizes vapor evaporating from the hot side of the distillation cycle and said vapor condenses on the cold side of the refrigeration cycle in the same chamber, without passing through a connecting tube.

14. As in claim 1, the said liquid is a mixture of glycol, water, salt and other contaminants and the distilled liquid is composed of distilled glycol and distilled water.

15. A stand-alone vacuum distillation device that incorporates a refrigeration cycle and uses a vacuum distillation method without a mechanical vacuum pump to produce distilled water as a product.

16. A stand-alone batch vacuum distillation device for distilling liquid, comprised of a heater vacuum generating device for generating vacuum pressure in said device, a distiller vessel in which said liquid is distilled, a connector tube connected between said distiller vessel and a distillate reservoir and a refrigeration unit.

17. The device of claim 16, where said refrigeration unit uses a vapor compression refrigeration cycle.

18. The device of claim 16, where said refrigeration unit uses an absorption refrigeration cycle.

19. The device of claim 16, wherein said heater vacuum generating device is comprised of a liquid supply connector tube, a heater element, a container for said heater element, and a vapor separator.

20. The device of claim 16 where a heat exchanger is added between the refrigerant evaporator I and the suction line from the refrigerant compressor which cools the refrigerant during the heater vacuum generating phase.

21. The device of claim 16, wherein said heater vacuum generating device is located at the center of said distiller vessel and is above the bottom of said distillate collector to minimize the contact area between the liquid and the vapor.

22. The device of claim 16, wherein said heater vacuum generating device is insulated.

23. The device of claim 16, wherein said enhanced circulation heat transfer device is comprised of said shroud and said refrigerant condenser.

24. The device of claim 16, wherein said distiller vessel is comprised of a refrigerant condenser, a shroud, a vapor separator, a refrigerant evaporator I, and a distillate collector.

25. As in claim 23, wherein said enhanced circulation heat transfer device consists of an additional heat source.

26. The device of claim 16, wherein said connector tube between said distiller vessel and said distillate reservoir is extended to the bottom of said distillate reservoir for condensing liquid vapor discharging from said distiller vessel during the vacuum generating phase.

27. The device of claim 16, wherein said distillate reservoir includes an air discharge vent and a distillate discharge valve.

28. The device of claim 16, which also includes an automatic control system for water filling, vacuum generating, distillate producing and distillate discharging phases.

29. As in claim 16, wherein the distillation device is integrated into a standard household refrigerator.

30. As in claim 29, where said water distillation device is combined with a refrigerant evaporator I.

31. As in claim 29, where said water distillation device is without said refrigerant evaporator I.

END OF CLAIMS SECTION

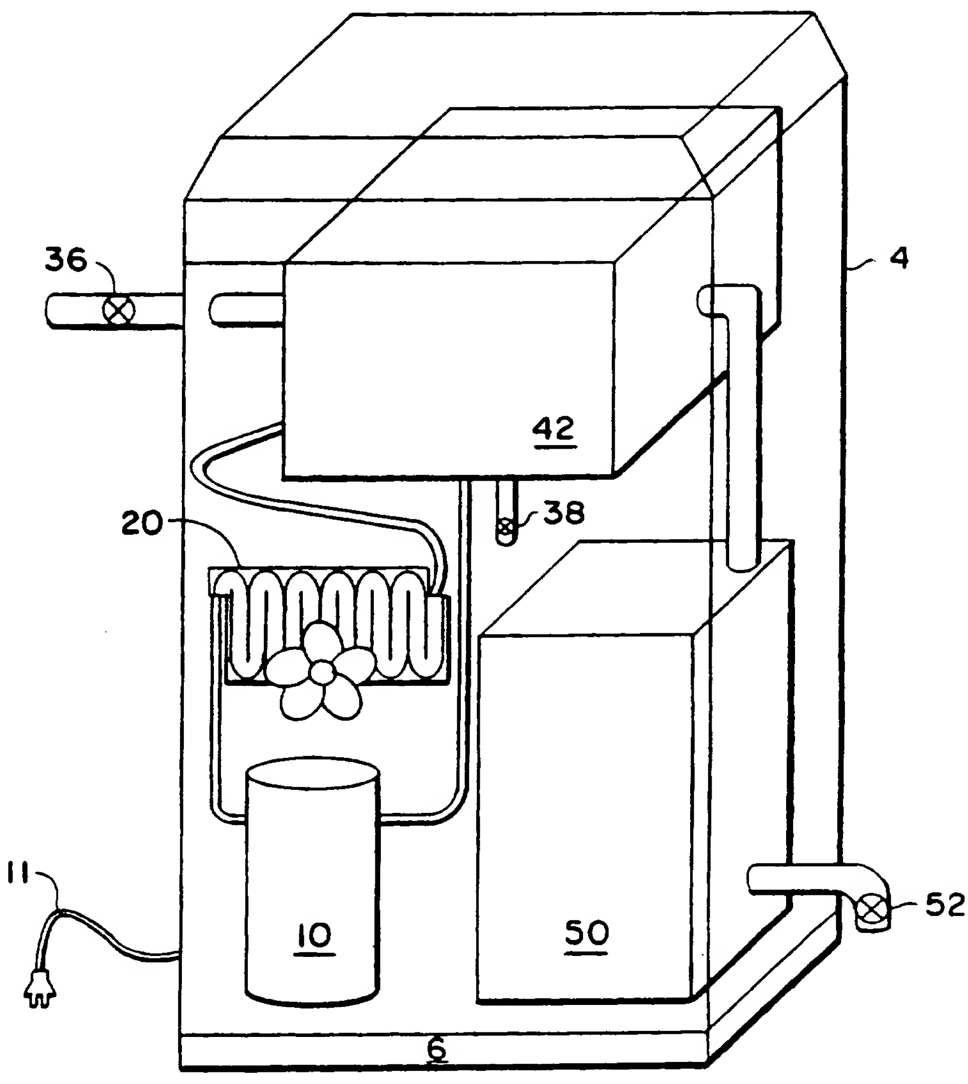

FIG. 1a

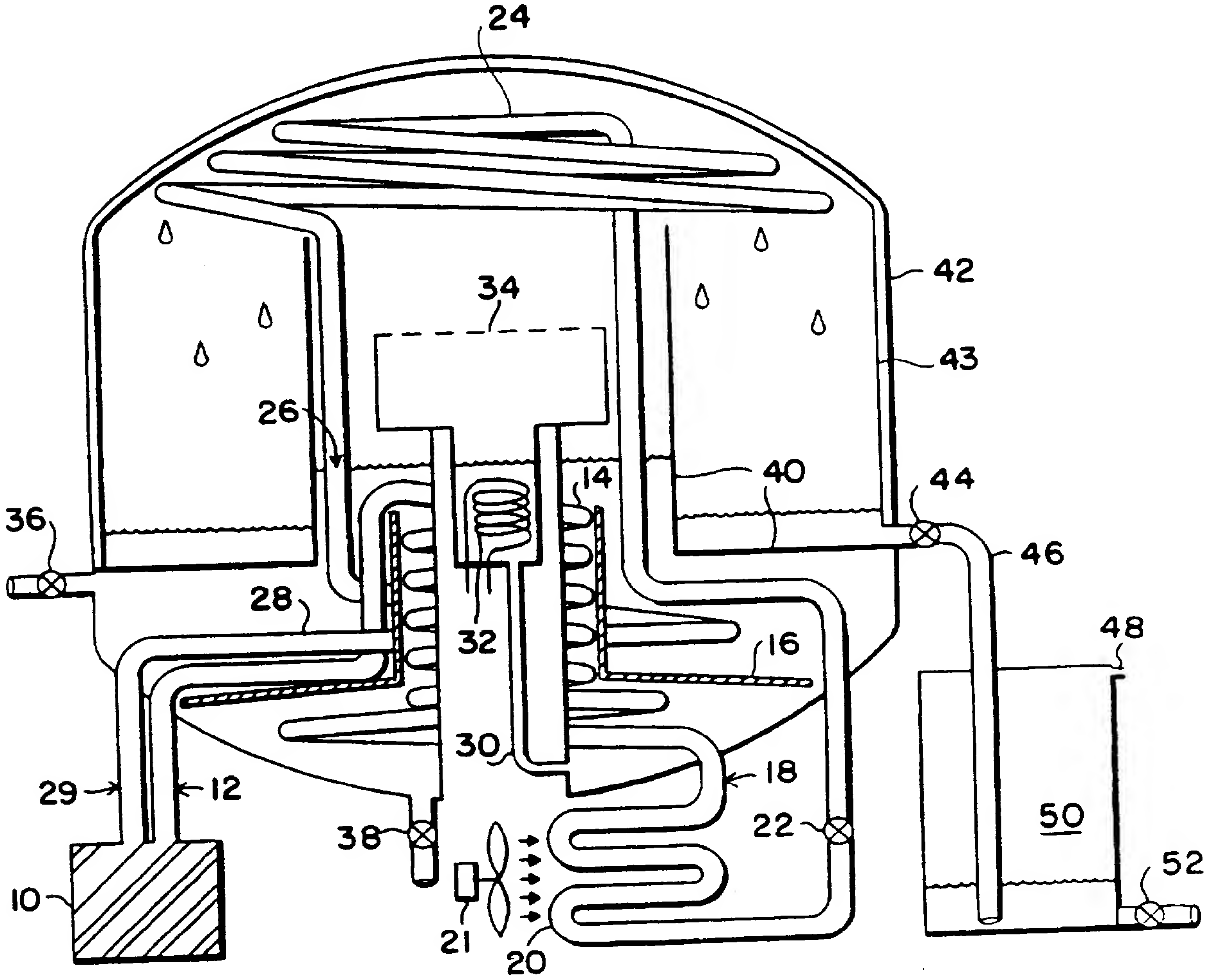
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FIG. 1b

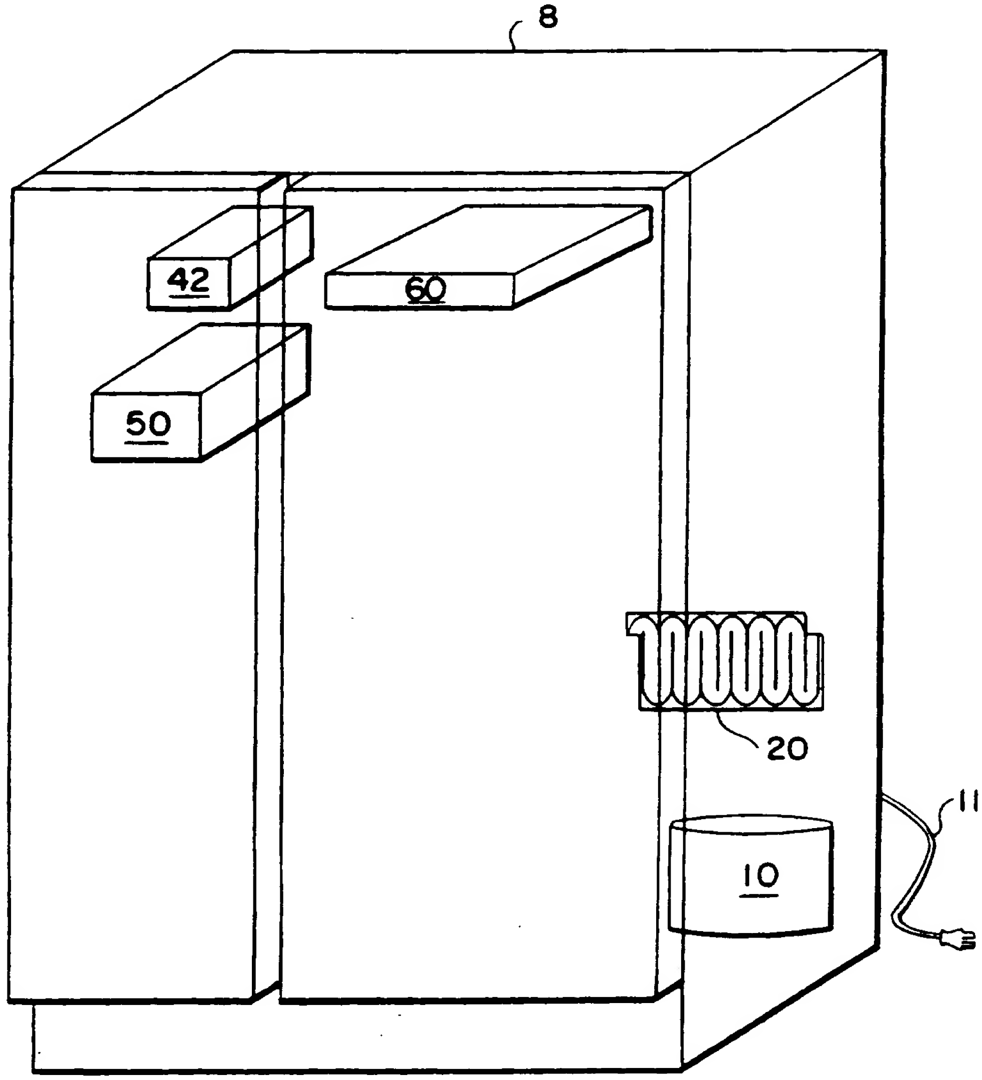

FIG.2a

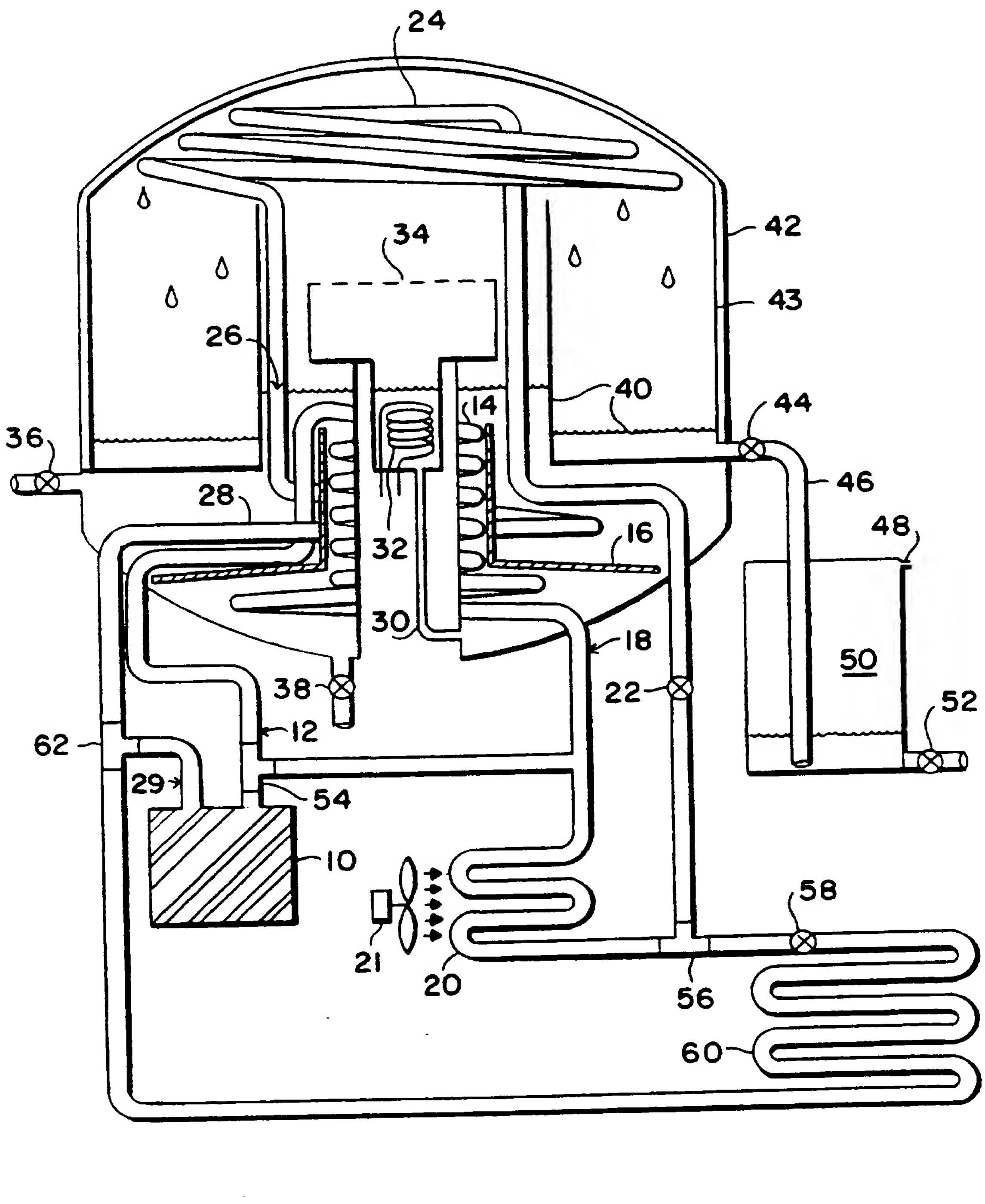
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FIG.2b

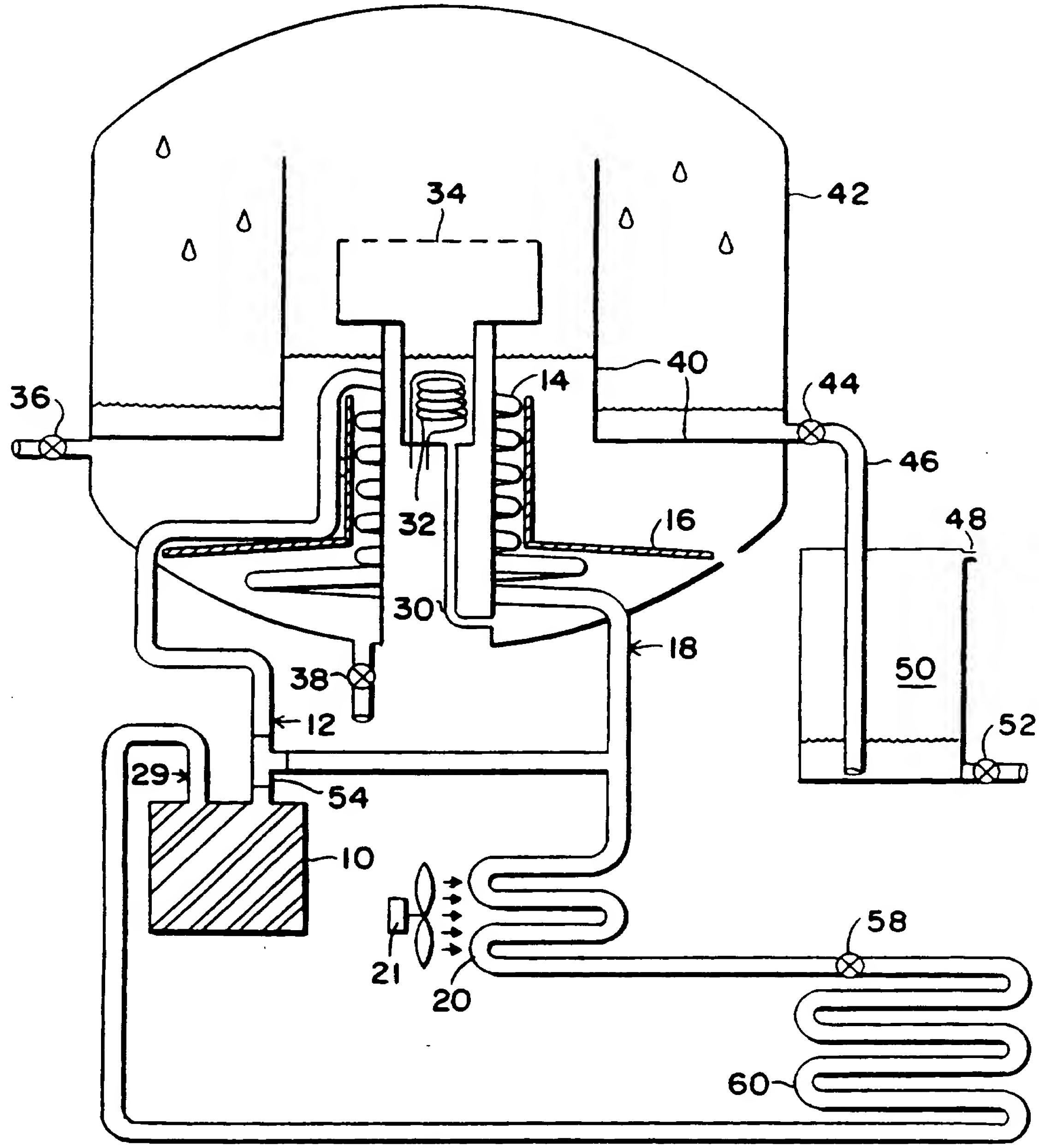

FIG. 2c

INTERN[redacted]ONAL SEARCH REPORT

[redacted] nal Application No
PCT/US 96/15042

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 B01D3/10 B01D3/02 B01D5/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 B01D

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X,P	US,A,5 511 388 (TAYLOR JAMES E ET AL) 30 April 1996 see column 1, line 66 - column 2, line 24 see column 3, line 19 - column 4, line 11; claims 1-35; figures 1,2,4 ---	1,5,10, 12,15,17
X	PATENT ABSTRACTS OF JAPAN vol. 013, no. 182 (C-591), 27 April 1989 & JP,A,01 011604 (YUTAKA TAKEUCHI), 17 January 1989, see abstract ---	1-5,8, 13,15
X	US,A,5 439 560 (KUREMATSU MASAYUKI ET AL) 8 August 1995 see column 6, line 24 - column 8, line 22 see column 7, line 6-18 see column 8, line 65 - column 9, line 31; figures 1,4 ---	1-5,8, 10,11,13

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[X] Further documents are listed in the continuation of box C.

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Date of the actual completion of the international search
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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP,A,0 006 612 (MCCORD JAMES W) 9 January 1980 see abstract; claims 1-37 see page 7, line 24 - page 8, line 27; figures 1-7 ---	1,5,7,8, 13,14
A	US,A,3 794 566 (RAAL J) 26 February 1974 see abstract ---	8
A	EP,A,0 269 191 (RECYCLENE PRODUCTS INC) 1 June 1988 see abstract; figure 1 -----	

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INTERNATIONAL SEARCH REPORT

Information on patent family members

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